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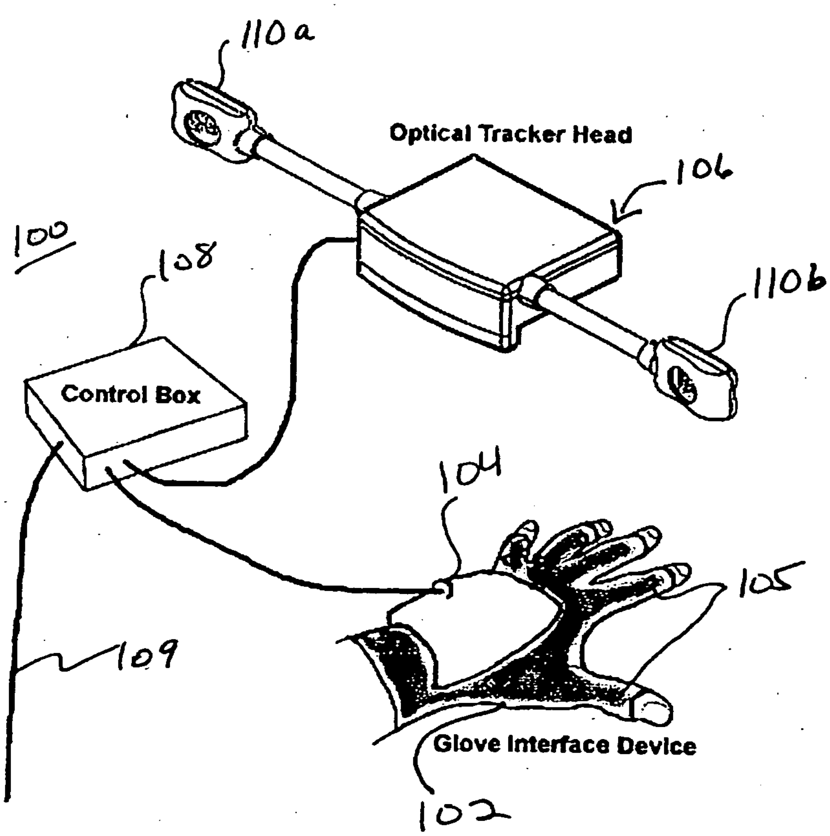

(57) Abstract: A user worn interface (102), such as a hand worn glove, necklace, ankle bracelet, sock, or shirt, includes embedded electronics (104), radiation sources (105), and sensor technologies (110a, 110b). Starting position and movement of the interface (102) is tracked on a computer monitor with electronics & firmware/software supporting X, Y and Z axis positioning. Electro-resistive sensors embedded within a surface of the interface (102) cooperate with an array of LEDs (105) located on a top surface of the interface (102) and a line of sight detection system to detect all motion, position, and gestures from specific movement of the user's body (e.g., thumb, finger digits and hand). The user's motions and positions are detected and processed to provide x, y, z and yaw, pitch, and roll data to a computer-based device.

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ELECTRONIC USER WORN INTERFACE DEVICE

RELATED APPLICATIONS

The present application claims the benefit of provisional patent application "Glove Interface Device", serial number 60/276,292, filed March 16, 2001 and a second provisional of the same title "Glove Interface Device", serial number 60/245,088, filed November 2, 2000. In addition, co-pending application entitled "Shadow Based Range and Direction Finder" is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of Invention

The present invention relates generally to the field of computer I/O devices. More specifically, the present invention is related to a multiple axis input device in the form of a body worn element.

Discussion of Prior Art

In the early 1980's, the Macintosh® computer was the first to use a Graphic User Interface (GUI) in widely accepted computer software. A GUI is a graphically based, mouse-centric user interface that makes use of icons, windows, buttons, menus, and dialog boxes which allow the user to select commands and manage programs, files, and folders by manipulating icons. The Macintosh system also made popular the use of the mouse which made manipulation of the on-screen environment simpler.

Computer applications, particularly in the gaming and design markets, have migrated from a two-dimensional visual interface to intuitive, real-world-

simulating three-dimensional visual interfaces. Since the advent of the mouse, however, little has changed in the way of input devices. Input devices have been dominated by two-dimensional products such as mice, keyboards, joysticks and proprietary console controllers because of prohibitively high prices for three-dimensional input devices.

What is needed is an inexpensive three-dimensional input device that serves users' needs for two-dimensional and three-dimensional software manipulation by providing a more intuitive and precise means of entering information - direct input that emulates the way humans interact with their offline environment.

The interface device of the present invention provides an input device that serves users' needs for 2D and 3D software manipulation by providing a more intuitive and precise means of entering information - direct input that emulates the way humans interact with their offline environment.

Video games are just one area that will benefit from the enhanced productivity of such an input device. Other areas include, but are not limited to, music composition and conduction, orchestration of lighting and sound control, material shaping and manipulation, web surfing and browsing and the like. The desire of consumers to literally grab a hold of the Internet will become a reality.

SUMMARY OF THE INVENTION

The input system of the present invention generally comprises a user worn interface, such as a hand worn glove, necklace, ankle bracelet, sock, or shirt, with electronics, radiation sources, and sensor technologies that provide for detecting a user's natural body motions (e.g., hands) and position in three-dimensional space.

The user's motions and positions are detected and processed to provide x,y,z and yaw, pitch, and roll data to a computer-based device.

The interface device, in the preferred glove embodiment, is engineered with up to five-finger bend sensitivity that provides full finger and wrist recognition and preferably includes web-imbedded software to provide Internet navigation. Up to five-finger bend sensitivity is achieved through the use of sensors (in the preferred embodiment **15**) embedded in the housing or "fabric" of the interface device. In addition, a pattern of radiation sources (in the preferred embodiment an array of **16**), such as LEDs, provide signals to a remote tracking device, able to track the position of the radiation sources in three dimensions. The device is lightweight and comfortable, incorporating customized and specialized materials.

A separate tracking station (working details of sensors provided in co-pending application "Shadow Based Range and Direction Finder") provides for a plurality of three-dimensional direction detectors used to determine the three-dimensional position of a radiating object (detected radiation sources from gloves' LEDs). The object's three-dimensional position is provided by a first two-dimensional direction of the radiating object in a plane defined by the first axis and the vertical that is determined from a ratio of the detected intensities of the incident radiation on each of a first pair of detectors. In addition, a second two-dimensional direction of the radiating object in a plane defined by the second axis and the vertical is determined from a ratio of the detected intensities of the incident radiation on each of the second pair of detectors. As shown in figure 7, the object's (**704**) distance from either of the three-dimensional direction detectors **700** and **702**

is determined and then, using triangulation with the known distance between detectors, the object's three-dimensional direction is detected.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a system diagram of a preferred embodiment of the present invention.

Figure 2 illustrates a system diagram of a second embodiment of the present invention.

Figure 3 illustrates a diagram of pitch, yaw and roll for a hand.

Figure 4 illustrates an electronics diagram of the system used in figure 1.

Figure 5 illustrates the triangulation technique used by the tracking system of the present invention.

Figure 6 illustrates a schematic of the detector geometry.

Figure 7 illustrates shadow when the detector of figure 6 is spaced apart from the filter.

Figure 8 illustrates detector head geometry.

Figure 9 illustrates reference frames.

Figure 10 illustrates creating a basis set given an arbitrary set of 3D positions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

There is depicted in the drawings, and will herein be described in detail, one or more preferred embodiments of the invention, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and the associated functional specifications for its practice and is not

intended to limit the invention to the embodiments illustrated. Those skilled in the art will envision many other possible variations within the scope of the present invention.

A first embodiment of the input device of the present invention generally comprises a system including a hand worn glove with electronics, light emitters and detectors, position tracker and associated circuitry, and a controller providing input to a computer based device such as a PC or gaming console. The system provides for detecting a user's natural hand motions, gestures and positioning in three-dimensional space. The relative movements of the user's hand motions and position to previously detected values provide the input to the computer-based device.

The preferred embodiment of the device consists of a hand worn glove with embedded electronics, radiation sources, and sensor technologies. Starting position and movement of the device will be tracked on a computer monitor with electronics & firmware/software supporting X, Y and Z axis positioning. The device of the invention is also capable of gesture recognition from specific movement of thumb and finger digits. Positioning and movement recognition of the glove like device is achieved through sensors positioned in strategic locations within the glove like device. Such sensors track finger bends and hand movements within conventional three-dimensional space to include pitch, yaw, and roll.

Figure 1 illustrates an embodiment of the input system **100** of the present invention. The system comprises glove **102** with embedded electronics **104**, sensors (not shown), sources of radiation **105** (LEDs), tracking head **106** for tracking position of sources of radiation, and computer interface electronics, which,

in this embodiment, are housed in a separate control box **108**. The electronics in control box **108** provide the data indicative of motion and position of a user's hand to a computer (not shown) through cable **109** (or equivalently through wireless transmission) to act as an input. The glove uses embedded electronics **104** to communicate specific movement of thumb and finger digits to control box **108**. This allows for the use of hand motion and gesture recognition as input. Tracker head **106** provides the three-dimensional position information, as recognized by the detection of position of radiation sources **105**, to control box **108**. The combined position and motion information allow a user's natural hand movements to be used as input.

Figure 2 illustrates the system of figure 1 with the control box **108** and tracking unit **106** (including tracking heads **110a** and **110b**) combined to form a single integrated station **107**. Monitor **114** from a connected PC or other equivalent computer system displays the data input by user control of glove **104**. While the illustration shows a single glove, alternative embodiments including multiple gloves are within the scope of the present invention.

The system tracks finger bends, hand movements, and position, all detected within conventional three-dimensional space. This enables the measurement of yaw, pitch and roll movements. Yaw, pitch and roll movements are depicted in figure 3. Yaw is defined as movement along a plane parallel to the ground. Yaw motion is achieved by holding your hand with your palm facing and parallel to the ground while rotating side to side on this horizontal plane. Pitch is defined as movement along an axis that is parallel to the top of your hand and perpendicular to the wrist, such that it would enter your wrist below your thumb and exit below

your little finger. Pitch is accomplished by moving your hand up and down while holding your forearm parallel to the ground. Roll is defined as rotation of your hand about an axis that is parallel to the ground and enters your hand at the tip of your middle finger and runs through your wrist parallel to your forearm. Roll is accomplished by holding your hand flat with your palm facing the ground and turning your arm such that your thumb rises and your little finger falls or vice versa.

Recognition of thumb and finger movement is achieved through sensors positioned in strategic locations within glove **102**, e.g., two sensors in each finger and an abduction sensor for the thumb. The sensing of finger bend or glove fabric stretch from finger movement will preferably occur via strip sensors or conductive inks with variable electrical resistance (such as, but not limited to, strain gauges, carbon-based inks on a flexible substrate). The position changes of hand digits are detected above a baseline bias voltage & resistance. Other types of sensors which sense finger positions (both knuckles per finger preferred) can be substituted without departing from the scope of the present invention.

Position of the user's hand is tracked by tracking head **106** using electronics and firmware/software supporting X, Y and Z axis positioning in conjunction with LEDs mounted on glove **102**. Preferably, 10-16 infrared LEDs **105** are mounted in three to four groups of four LEDs. However, variations of number and patterns of LEDs are within the scope of the present invention. LEDs radiating in other ranges of the electromagnetic spectrum, including visual light, are also considered within the scope of the present invention. Each group of LEDs are preferably placed in different areas around the hand to ensure at least one set of 3 of LEDs has line-of-

sight with tracking head **106**, regardless of hand orientation. Within each group, LEDs are preferably arranged in a pattern as to provide a non-coplanar configuration, with the ideal configuration being a triangular based pyramid configuration. These LEDs make glove **102** a point source of radiation that is tracked by tracking head **106**.

The complete three-dimensional position of glove **102** is determined using tracking head **106**. Tracker head **106** employs at least two three-dimensional direction detectors **110a** and **110b** placed a known distance away from each other for determining the glove's three-dimensional position. This is conceptually illustrated in figure 5. A three-dimensional direction detector **500** is placed at a point A. A second similar detector **502** is placed at a point B. Points A and B are separated by a known distance, d, along what is normally called a baseline. Detector **500** measures the three-dimensional direction of a radiating object **504** from point A. Likewise, detector **502** measures the three-dimensional direction of radiating object **504** from point B. Once both the directions are determined, triangulation is used to calculate the distance of the object from either point A or B. As can be seen, this arrangement allows the complete three-dimensional position of radiating source **500** to be measured as the distance and the three-dimensional direction of the radiating object from either detector.

These three-dimensional direction detectors have a number of advantages:

- The incident radiation is not restricted by an aperture and one of the planar detectors is always fully illuminated. On a relative scale, the individual signals from each planar detector "range" from 1 (at head on) to zero, and the total signal resulting from the four planar

detectors ranges from 4 (at head on) to 2. This is a significant improvement from the Marquet method where the signal ranges from 1/4th to 1.

- A large fraction of the detector area is always illuminated providing much larger usable ranges than previous systems.
- One detector for each direction is fully illuminated at all angles and its signal provides normalization.
- The detectors are arranged on the same plane, which minimizes mounting difficulties and expenses. In addition, there is not a need for accurately aligned angular positioning of the detectors.
- Any detector element including inexpensive solar cells could be utilized.
- Expensive optical elements, such as mirrors or lenses, are not needed.
- The planar detectors do not have to be arranged in very close proximity to each other as is required with a central aperture. Therefore, inexpensive, single planar detectors can be used rather than expensive, segmented planar detectors
- Light strikes both detectors of a single axis pair at the same angle. Thus, any deviation from Lambertian behavior affects both of them in the same way. Because of this, and the fact that only intensity ratios are used for the calculations, the accuracy of the measurement is not altered by the incident angle.

In an additional embodiment, the radiation from the source is modulated and detection is done at the modulation frequency only. This provides for discrimination from ambient radiation. In addition, this technique provides the ability to measure position information for several sources. The signals from different sources are made distinguishable using any modulation technique such as FDM, TDM, PCM, etc. Through suitable decoding at the detector end the positions of all the sources are then found at the same time. Thus, the system can be easily extended for simultaneous detection of several radiating sources, the number of sources being limited only by data processing speeds and capacities.

Each group of LEDs are preferably placed in different areas around the hand, in order to ensure line of sight with the optical tracker head that is preferably located at the back corner of a mounting bar which may have adjustable length. This bar will be attached to a "docking station" which can be placed on the users desk or tabletop. The "docking station" may contain a provision to assist in installation & removal of the glove like device from the users hand. The "docking station" may be used as a storage location for the glove like device. Within the "docking station" there will be housing for various electronic components.

The control box **108** (FIG. 1) houses the USB controller and preferably has one USB cable (host PC connection), and two cables that attach to the glove and the optical tracker head. The control box comprises a USB controller, an oscillator, filter capacitors and an analog multiplexer chip. A representative USB based micro controller that meets the needs of the present system might comprise a 6 MIPS, RISC core with built in 8 channel 8-bit Analog-To-Digital converters.

The USB controller preferably has enough code space for 8K instructions and is an in-system, programmable chip. Such controller also preferably incorporates FLASH memory, which allows for downloading of new program updates, bug fixes, etc. directly into the USB controller from the host computer.

The interface device is preferably a USB product to allow for direct "plug and play" in PCs and gaming consoles. A block diagram of the interface device is shown in FIG. 4. PCs on the market today are fully USB-ready, as well as the newest gaming consoles by Sony, Sega, Nintendo and Microsoft. The device of the invention is designed as a natural interface for the personal computer, stand-alone video gaming consoles and all other USB-compatible 3D software platforms, and acts as a peripheral to a PC, Mac/Apple and gaming consoles. Its operational performance is ultimately dependent on the motherboard, RAM, graphics card and monitor capability of the user's CPU, and the device of the invention will communicate with the CPU via a USB port.

As shown, the system comprises the tracker circuitry **402**, control box circuitry **404**, and glove circuitry **406**. The tracker circuitry includes a main section **412** including an optical tracking multiplexing board, differential amplifiers, DiffLV, DiffRV, DiffLH, DiffRH, SumL, SumR, DiffB, and power distribution, left and right tracking detector heads **408**, output amps for the heads **410**, associated signal transferring MUX **414**, and connectors for cables **416**.

The controller box **404** includes a micro controller and supporting components such as flash memory, crystal for clock/timing, various analog control circuitry **420**, power supply **422**, and connectors **424** and USB **426** connection to a computer or electronic based device such as a PC or gaming console.

The glove circuitry **406** includes an LED array (16) and associated decoders and drivers **429** analog bend sensors **430** (8) and **432**(7) and associated interfaces MUX's **431**. The LEDs are driven to output light signals and the bend sensors return signals of movement (typically based on a strain(change of capacitance) of the electro-resistive strip sensors). The routing of signals is controlled through **434** and may be hardwired, programmable or preprogrammed by conventional means. Connector **436** provides I/O of signals to the controller **404**.

Tracker Algorithm

An algorithm to determine angles and positions from the LEDs can be broken down into three major steps. The first step is to determine the angle of entry (horizontal and vertical) of the light from an individual LED into the detector heads. The next step involves triangulation in order to determine positional information of each LED in space. The final step is to calculate the orientation of the entire hand, given the positional information of all the LEDs in space.

Step 1 – Calculating angle of entry

Referring to Figure 6:

Height of wall, OA = h

Length of detector, BD = L

Length of shadow, OC = x

Dist from foot of the wall to edge of detector, OB = d

Width of detector = w

$\tan\theta = x/h$

$OC = x = h \tan\theta$

shadowed portion of the detector, $BC = OC\text{-}OB = h \tan\theta - d$

So, illuminated portion, $CD = BD\text{-}BC = L - (h \tan\theta - d) = (L - h \tan\theta + d)$

Signal from det #2, $I_2 = kLw$

Signal from det #1, $I_1 = kw\,(L - h \tan\theta + d)$

Where k is a proportionality factor, and includes, detector sensitivity, system gain etc. It is assumed to be same for both channels.

So the ratio, $R = (I_2 - I_1)/I_1 = [\,kLw - \{kw\,(1 - h \tan\theta + d)\}]/kLw$

$= (h \tan\theta - d)/L$

So, $\tan\theta = (LR + d)/h$

$\theta = \arctan\,[(LR + d)/h]$

This assumes that the detector is right at the surface of the package. Refraction in the filter requires a correction. Looking at the figure we see that the shadow is lengthened when there is a filter. If the filter is bonded to the detector, than the extra shadow length by EF is calculated:

$EF = \tan\varphi$

$\sin\theta = n \sin\varphi$

Taking $\sin\theta = \tan\theta$ and $\sin\varphi = \tan\varphi$, we have

$EF = \tan\theta/n$

So, the illuminated area $= lw - lw(h\tan\theta + t\tan\theta/n - d)$

$$= lw[1-\tan\theta(h + t/n) + d]$$

ie. h is replaced by $(h + t/n)$

So, the solution becomes:

$\theta = \arctan[(LR + d)/(h + t/n]$

for values of $h = 4$ mm, $t = 0.5$ mm and $n = 1.5$, the correction amounts to about 0.3 in 4.0

Referring to Figure 7, where showing the shadow when the detector is spaced s apart from the filter

If the filter is not bonded to the detector and there is an air/ vacuum spacing of 's' between the two as in figure overleaf,

The formula becomes:

$\boldsymbol{\theta = \arctan[(LR + d)/(h + t/n + s]}$

assuming,

$L = w = 3$ mm

And the cathode edge of the detector is at $(2.15 - 1.5) = 0.65$ mm from the package edge.

So, d, is quite close to 0.65 mm.

Step 2 – Triangulating position information

Referring to Figure 8:

Once the horizontal and vertical angle of entries to both detector heads has been determined, we can triangulate the x,y,z position of the LED.

From the diagram above, O_1 and O_2 represent the two detector heads, located on a common X-axis. Y_1 and Y_2 are the two Y-axes and Z_1, Z_2 the two Z-axes. D is the LED position.

Its projection in the XZ_1 plane is O_1C subtending an angle $\theta_1$with the Z_1. The projection in the Y_1Z_1 plane is O_1F subtending an angle φ_1. The corresponding angles from the second detector O_2 are θ_2 and φ_2. Since the detectors are displaced only along the X axis, $\varphi_1 = \varphi_2$, $Y_1 = Y_2 = Y$ and $Z_1 = Z_2 = Z$

- Caution: These are the angles measured by the X & Y sets of detectors in a direction finder, and are different from the angles θ and φ that are normally defined and used for calculating directional cosines.

$Z_1 = Z_2 = O_1A = O_2B = Z$ say, common to both

$X_1 = O_1K = AC = Z \tan \theta_1$

$X_2 = O_2K = BC = Z \tan \theta_2$

$X_1 = X_2 + d$

Therefore, $Z \tan \theta_1 = Z \tan \theta_2 + d$

$Z (\tan \theta_1 - \tan \theta_2) = d$

$\mathbf{Z = d/(\tan \theta_1 - \tan \theta_2)}$

So, $X_1 = d/(\tan \theta_1 - \tan \theta_2)^* \tan \theta_1$ and

$\mathbf{X_2 = d/(\tan \theta_1 - \tan \theta_2)^* \tan \theta_2}$

$Y_1 = O_1G = AF = Z \tan \varphi_1 = Y_1 = O_2H = BE = Z \tan \varphi_2$

$\mathbf{Y_1 = Y_2 = Y = d/(\tan \theta_1 - \tan \theta_2)^* \tan \varphi_2}$

The formulas are exact and provide the correct sign + or –

For the above formulas, it is not necessary to even calculate the tan of the angle, as this value can be obtained directly from the detector head calculation performed in the previous step.

Step 3 – Calculating orientation information

Referring to Figure 9:

At this stage, we have the x, y, z position information of all visible LEDs in the camera frame of reference.

There are three main frames of reference that must be described. The first frame is the world co-ordinate frame (Frame 0), which in our geometry can be considered to be the camera frame of reference. Then, there is another frame of reference, which is the hand's or wrist frame of reference, in which all LEDs are placed in (Frame 1). Finally, we can also create another frame of reference using a specific group of 3 LEDs (Frame 2). It should be noted that Frame 2 is constant with respect to Frame 1, and Frame 1 is moving with respect to Frame 0 as the user moves the system in space.

The following is an arbitrary rotation matrix $R = R_{z,\phi,} * R_{y,\Theta} * R_{x,\psi}$. Where ϕ is the roll, Θ is the pitch and ψ is the yaw of the system.

$$\begin{array}{ccc} i & j & k \end{array}$$
$$\begin{bmatrix} \cos\phi\cos\Theta & -\sin\phi\cos\psi+\cos\phi\sin\Theta\sin\psi & \sin\phi\sin\psi+\cos\phi\sin\Theta\cos\psi \\ \sin\phi\cos\Theta & \cos\phi\cos\psi+\sin\phi\sin\Theta\sin\psi & -\cos\phi\sin\psi+\sin\phi\sin\Theta\cos\psi \end{bmatrix}$$

$-\sin\Theta$ $\cos\Theta\sin\psi$ $\cos\Theta\cos\psi$

Given this general matrix, the columns of the matrix form the basis vectors for the transformed space. Inversely, given a set of basis vectors (i, j, k) for a general space, one can easily create a rotation matrix, which transforms points from the absolute world frame to the relative world frame.

For the problem, we need to obtain the transformation matrix $R_{0\to1}$.

$$R_{0\to2} = R_{0\to1} R_{1\to2}$$

$$R_{0\to2} [R_{1\to2}]^t = R_{0\to1} R_{1\to2} [R_{1\to2}]^t$$

$$R_{0\to2} [R_{1\to2}]^t = R_{0\to1}$$ The inverse of a transformation is its transpose.

Hence, $\mathbf{R_{0\to1} = R_{0\to2} [R_{1\to2}]^t}$

From this equation, we can calculate the transformation matrix that takes points from the camera frame to the wrist frame (frame 0 to frame 1). To obtain $R_{0\to2}$, we just create a basis set from the LEDs visible to the camera and create the rotation matrix. $R_{1\to2}$ can be calculated by measuring the physical geometry of the same LEDs with respect to an origin on the hand, the same way.

In order to create a basis set given an arbitrary set of 3D positions, the following algorithm can be used (referring to Figure 10).

By creating 2 vectors with the known points (A, B), we can create a set of basis vectors: A, AXB, AX(AXB). After normalizing these vectors as the i, j and k column vectors, we obtain a rotation matrix $R_{0->2}$. By using the exact same points and the same calculations, we can also create the matrix $[R_{1->2}]^t$. Using these two matrices, we can now calculate $R_{0->1}$.

The actual angles can be calculated by setting the $R_{0->1}$ matrix to equal the general yaw\pitch\roll matrix described above, and solving for the angles.

$$\Theta = \sin^{-1}(-\mathbf{R}_{0->1[3,1]})$$

$$\psi = \tan^{-1}(\mathbf{R}_{0->1[3,2]}/\ \mathbf{R}_{0->1[3,3]})$$

$$\phi = \tan^{-1}(\mathbf{R}_{0->1[2,1]}/\ \mathbf{R}_{0->1[1,1]})$$

These are the angles that we need. This will work in the first quadrant. The other quadrants can be found using a combination of the signs of the matrix elements.

Professionals in a wide range of computer-aided design (CAD) applications use 3D visualization tools. Architects, game designers, product designers, mechanical designers, construction engineers and cartoon movie makers all use PC-based design software to create, manipulate and animate in 3D. This market's needs are distinct from those of the gaming market in that the users seek to create 3D objects--rather than simply manipulate them--which traditionally requires a time-consuming, multi-action process.

Currently, all software is designed for four primary input devices: keyboard, mouse, light pen and digitizing tablets. While the tasks enabled by certain devices (namely drawing with digitizing tablets) are useful, the software in general has proven consistently frustrating to its user base, primarily because it is so difficult to learn.

Applications for this market can be distilled into four segments based upon the software used and the functionality requirements of the group. These segments are the Architecture, Engineering and Construction (AEC) market, the Mechanical Engineering (ME, or MCAD for Mechanical Computer-aided Design) market, the Game Developer market and the Film/Video market.

In its simplest iteration, the glove device of the present invention will replicate the existing mouse or controller commands built into current applications. However, with awareness of the extended capabilities of the device of the invention, a developer will be able to create entirely new commands and user interfaces for existing and future applications. A current computer user interface will evolve to a 3D interface as programming languages and bandwidth enabling larger file sizes arrives.

The primary users are Internet browsing households. Research shows that all members of the family in PC-owning households are using the PC, and for different reasons. Online, they are all using the Internet, and again for different reasons. The advent of broadband will be the primary incentive for 3D designers to produce content for the average Internet user. This will enable web developers to incorporate real-looking objects into e-Commerce sites, create desktops and browsers which look like real rooms and require manipulation through a 3D space,

and ultimately change the entire Internet experience for the PC user. The glove, or other body worn device, of the present invention will enable all users to work intuitively within this environment.

The glove interface device of the present invention is a peripheral device adapted for use with the computer and gaming console market. The device of the invention is designed for multiple uses including but not limited to: gaming, scientific visualization, animation, Computer Aided Design (CAD), virtual reality, industrial design, training and education, and web browsing. Such glove device serves as an interface for a personal computer, stand-alone video gaming console or other USB devices, and is provided with a multiplicity of sensors to accurately determine and track the position of the user's body parts, such as hand, wrist and five fingers in space.

CONCLUSION

A system and method has been shown in the above embodiments for the effective implementation of a user worn interface device. While various preferred embodiments have been shown and described, it will be understood that there is no intent to limit the invention by such disclosure, but rather, it is intended to cover all modifications and alternate constructions falling within the spirit and scope of the invention, as defined in the appended claims. For example, the present invention should not be limited by software/program, computing environment, specific computing hardware, or specific LED or sensor numbers, patterns or placement.

In addition, as 2-way tactile feedback technology progresses, opportunities will result: remote robotic operation, "Braille" websites for the blind, online shopping where you can feel the fabric, education on a whole new level, surgery

conducted with doctor and patient located on opposite coasts. Alternative embodiments of the glove device incorporating enhancements and feature options include a wireless product, the ability to monitor sweat and pulse, the ability to provide and utilize tactile feedback and the ability to interchange the glove fabrics through the use of removable electronics.

The above enhancements for icons and its described functional elements are implemented in various computing environments. For example, the present invention may be implemented on a conventional IBM PC or equivalent, multi-nodal system (e.g., LAN) or networking system (e.g., Internet, WWW, wireless web). All programming and data related thereto are stored in computer memory, static or dynamic, and may be retrieved by the user in any of: conventional computer storage, display (i.e. CRT) and/or hardcopy (i.e. printed) formats. The programming of the present invention may be implemented by one of skill in the art of GUI and I/O device programming.

CLAIMS

What is claimed is:

1. A computer interface providing data input to a computer based system, said computer interface comprising:

an electronic user worn device, said device operatively connected to said computer based system and comprising:

a plurality of embedded electro-resistive sensors;

an array of radiation emitters, said emitters located on an exterior surface of said device;

a position tracker device operative with said array of radiation emitters to track position of said emitters,

a processing controller, said controller operatively connected to outputs from said embedded electro-resistive sensors and an output of said position tracker, and

wherein said processing controller receives data from said sensors and said position tracker and transfers a computer interface input representing motion and position of said device to said computer interface.

2. A computer interface as per claim 1, wherein said electronic user worn device comprises any of: a flexible glove, necklace, ankle bracelet, sock, or shirt.

3. A computer interface as per claim 1, wherein said electro-resistive sensors comprise ink deposited on a flexible substrate.

4. A computer interface as per claim 1, wherein said radiation emitters comprise LEDs.

5. A computer interface as per claim 1, wherein said computer based device includes any of: a personal computer, stand-alone video gaming console, or USB devices.

6. A computer interface as per claim 1, wherein said interface accurately tracks the position of any, or a combination of: a user's hand, wrist, individual fingers, legs, feet, head, torso.

7. A computer interface as per claim 1, wherein said interface includes web-imbedded code to assist in Internet navigation.

8. A computer interface as per claim 1, wherein said operative connection to said computer based device comprises any of : standard cable connection, USB , or wireless connection.

9. A computer interface as per claim 8, wherein said USB connection provides plug and play capability.

10. A computer interface as per claim 2, wherein said interface recognizes gestures performed by detection of coordinated movements of said flexible glove.

11. A computer interface as per claim 2, wherein said interface measures yaw, pitch and roll movements of said flexible glove.

12. A computer interface as per claim 1, wherein said array of radiation emitters provide inputs to horizontal and vertical detector clusters mounted on said position tracker device.

13. A computer interface as per claim 1, wherein said computer interface further comprises a docking station for said device.

14. A computer interface as per claim 1, wherein said interface tracks six degrees of motion, including x, y, z, yaw, pitch, and roll.

15. A computer interface as per claim 1, wherein said interface is applied to any of: music composition and conduction, orchestration of lighting and sound control, material shaping and manipulation, and web surfing and browsing.

16. A method to provide positional input to a computer based system using an electronic interface, said interface comprising: a user wearable device, a plurality of embedded sensors, an array of embedded radiation emitters, a position tracker device operative with said array of radiation emitters, and a processing controller, said method comprising:

detecting movement signals from said sensors, said signals indicating specific user body specific movements;

detecting at said position tracker device position signals from said array of radiation emitters;

processing said movement and position signals to output a data input signal to said computer based system, and

wherein said data input signal representing motion and position of said user wearable device is provided to an application interface of said computer based system.

17. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said step of detecting movement signals from said sensors further comprises detecting a change of resistance produced in said sensors.

18. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said sensors comprise ink deposited on a flexible substrate.

19. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said array of radiation emitters comprise LEDs.

20. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said computer based system comprises any of: a personal computer, stand-alone video gaming console, or USB device.

21. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said method accurately tracks the position of any, or a combination of: a user's hand, wrist, individual fingers, legs, feet, head, torso.

22. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said method assists a user in Internet navigation.

23. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein a USB connection provides plug and play capability.

24. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said method recognizes gestures performed by detection of coordinated movements of said interface.

25. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said interface tracks six degrees of motion, including x, y, z, yaw, pitch, and roll.

26. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said interface is applied to any of: music composition and conduction, orchestration of lighting and sound control, material shaping and manipulation, and web surfing and browsing

27. A method to provide data input to a computer based system using an electronic interface as per claim 16, wherein said user wearable device comprises any of: a flexible glove, necklace, ankle bracelet, sock, or shirt.

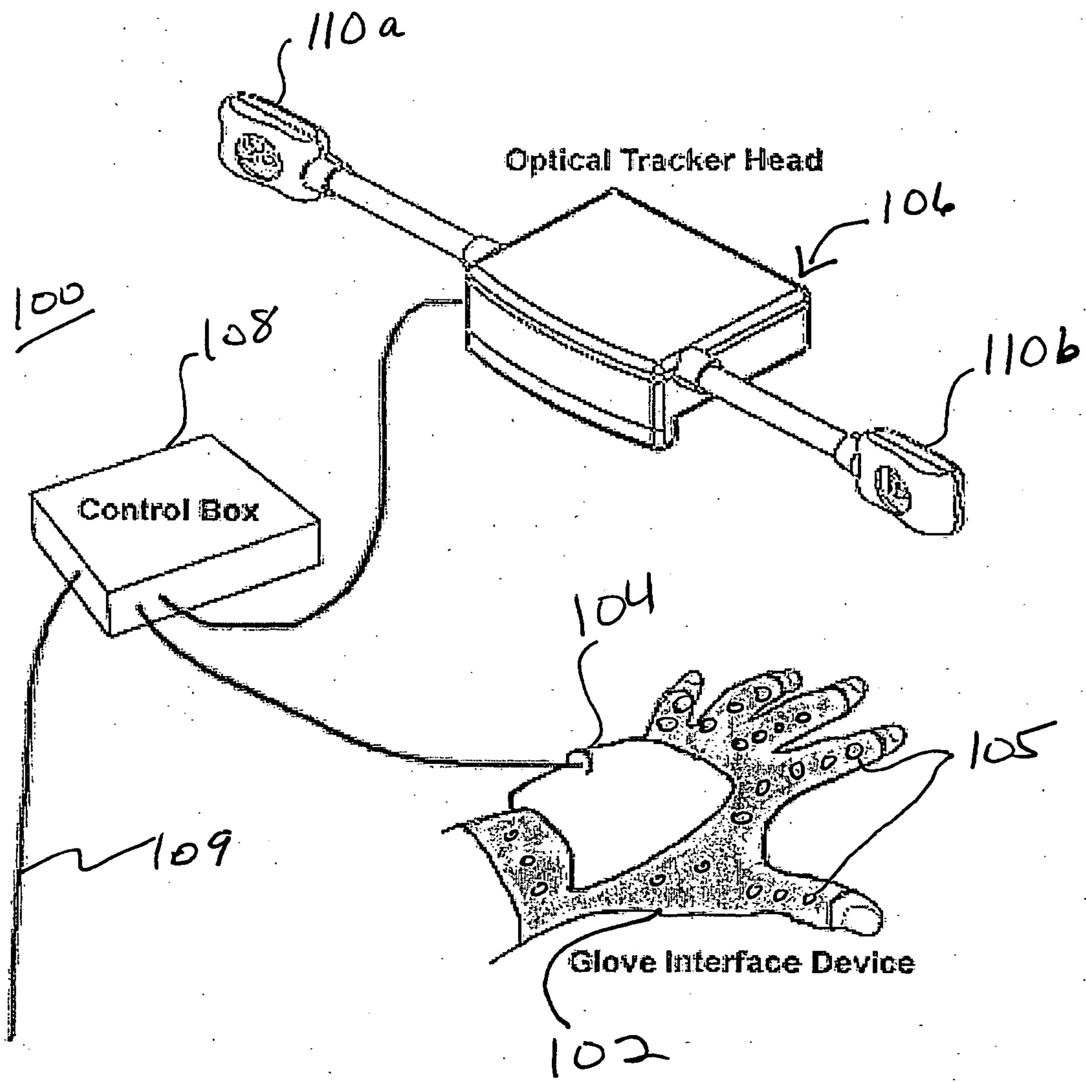
110a
Optical Tracker Head
106
100
108
110b
Control Box
104
105
109
Glove Interface Device
102

Figure 1

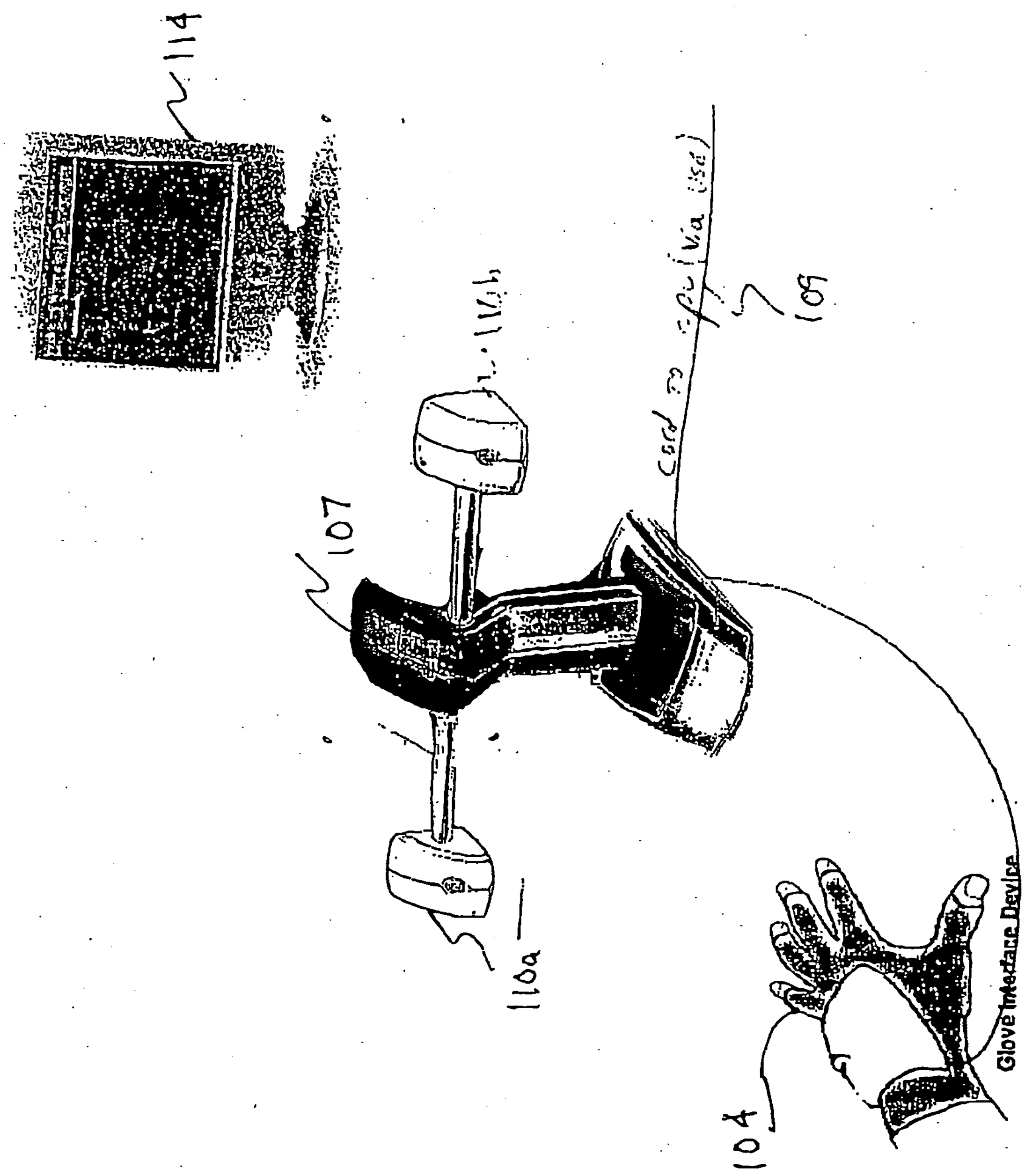

Figure 2

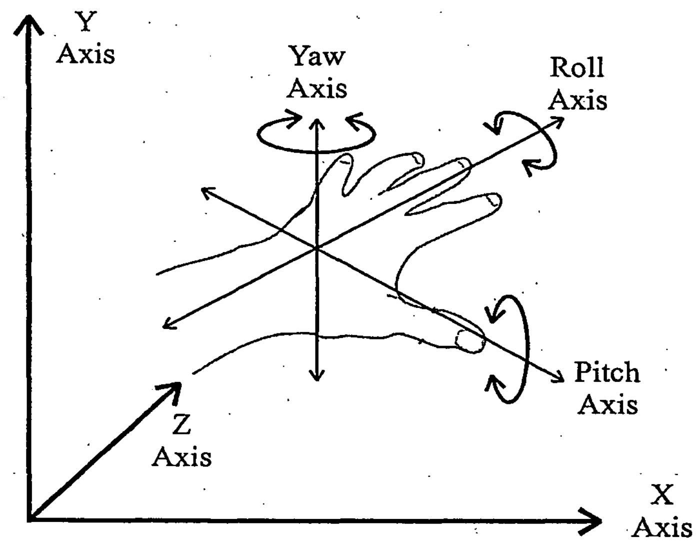

Figure 3

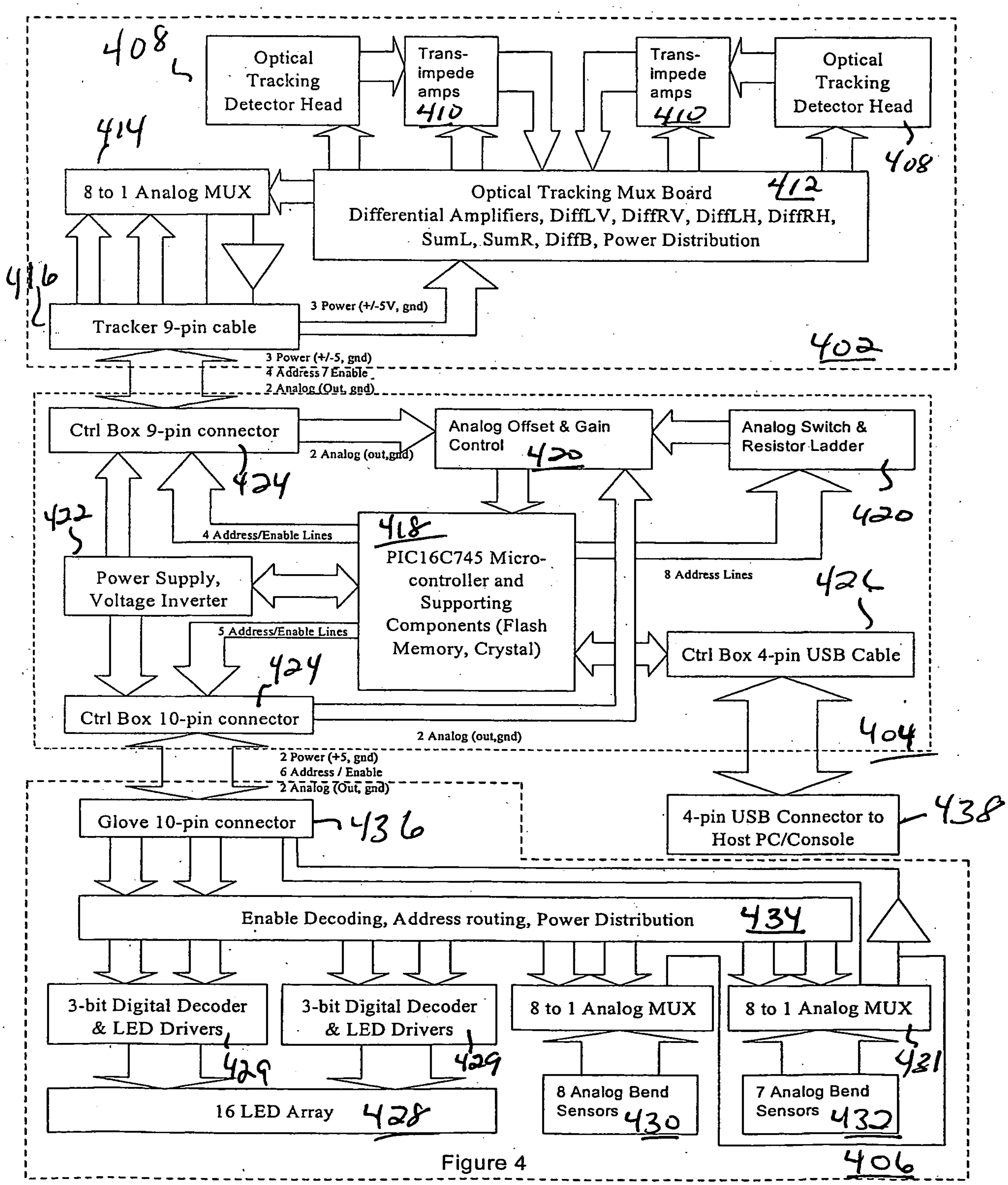
408
Optical Tracking Detector Head
Trans-impede amps 410
Trans-impede amps 410
Optical Tracking Detector Head
408
414
8 to 1 Analog MUX
Optical Tracking Mux Board 412
Differential Amplifiers, DiffLV, DiffRV, DiffLH, DiffRH, SumL, SumR, DiffB, Power Distribution
416
Tracker 9-pin cable
3 Power (+/-5V, gnd)
402
3 Power (+/-5, gnd)
4 Address 7 Enable
2 Analog (Out, gnd)
Ctrl Box 9-pin connector
2 Analog (out,gnd)
Analog Offset & Gain Control 420
Analog Switch & Resistor Ladder
420
424
422
4 Address/Enable Lines
418
PIC16C745 Micro-controller and Supporting Components (Flash Memory, Crystal)
8 Address Lines
426
Power Supply, Voltage Inverter
5 Address/Enable Lines
424
Ctrl Box 4-pin USB Cable
Ctrl Box 10-pin connector
2 Analog (out,gnd)
404
2 Power (+5, gnd)
6 Address / Enable
2 Analog (Out, gnd)
Glove 10-pin connector 436
4-pin USB Connector to Host PC/Console 438
Enable Decoding, Address routing, Power Distribution 434
3-bit Digital Decoder & LED Drivers
3-bit Digital Decoder & LED Drivers
8 to 1 Analog MUX
8 to 1 Analog MUX
429
429
431
16 LED Array 428
8 Analog Bend Sensors 430
7 Analog Bend Sensors 432
406

Figure 4

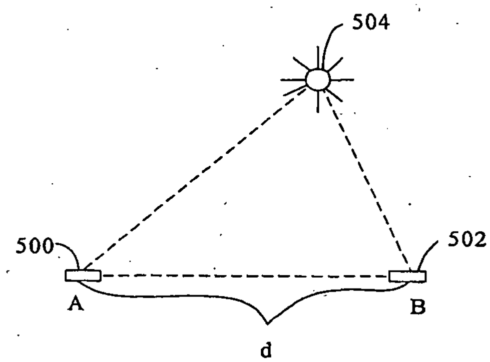

Figure 5

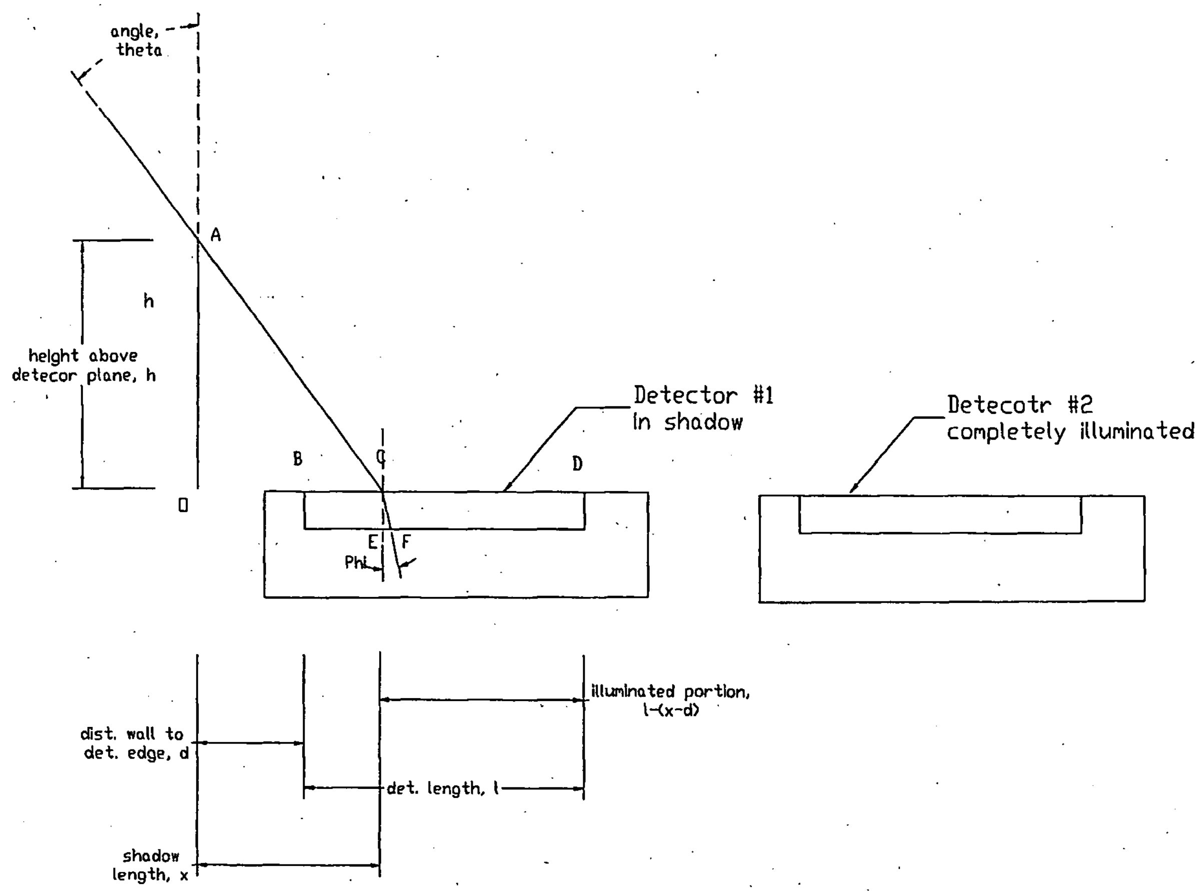
angle, theta
A
h
height above detecor plane, h
Detector #1 in shadow
Detecotr #2 completely illuminated
B
C
D
O
E
F
Phi
illuminated portion, l-(x-d)
dist. wall to det. edge, d
det. length, l
shadow length, x

Figure 6

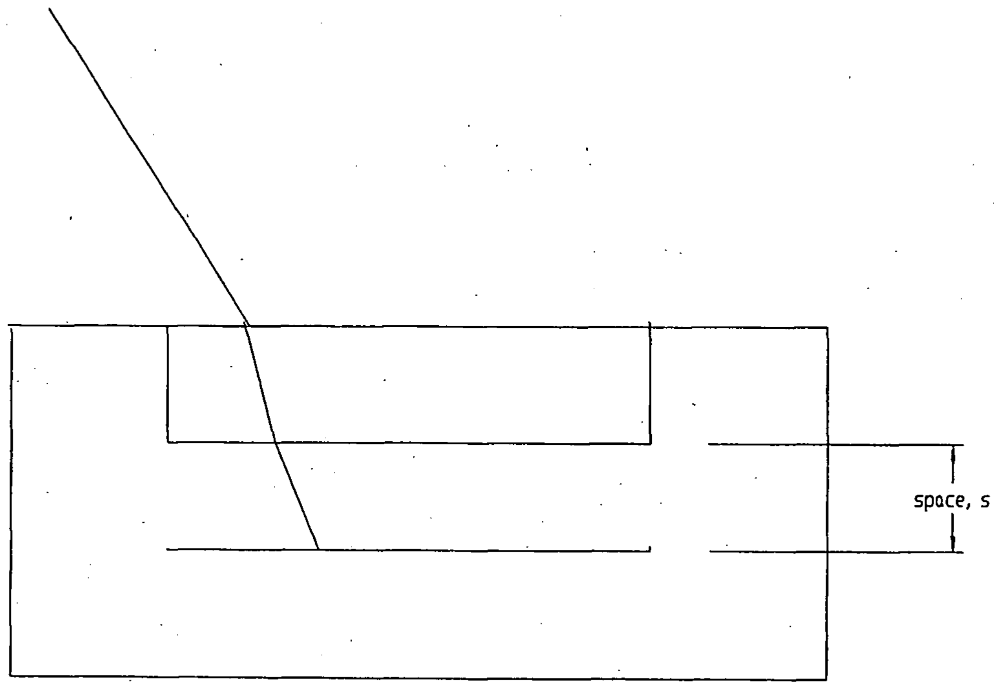

Figure 7

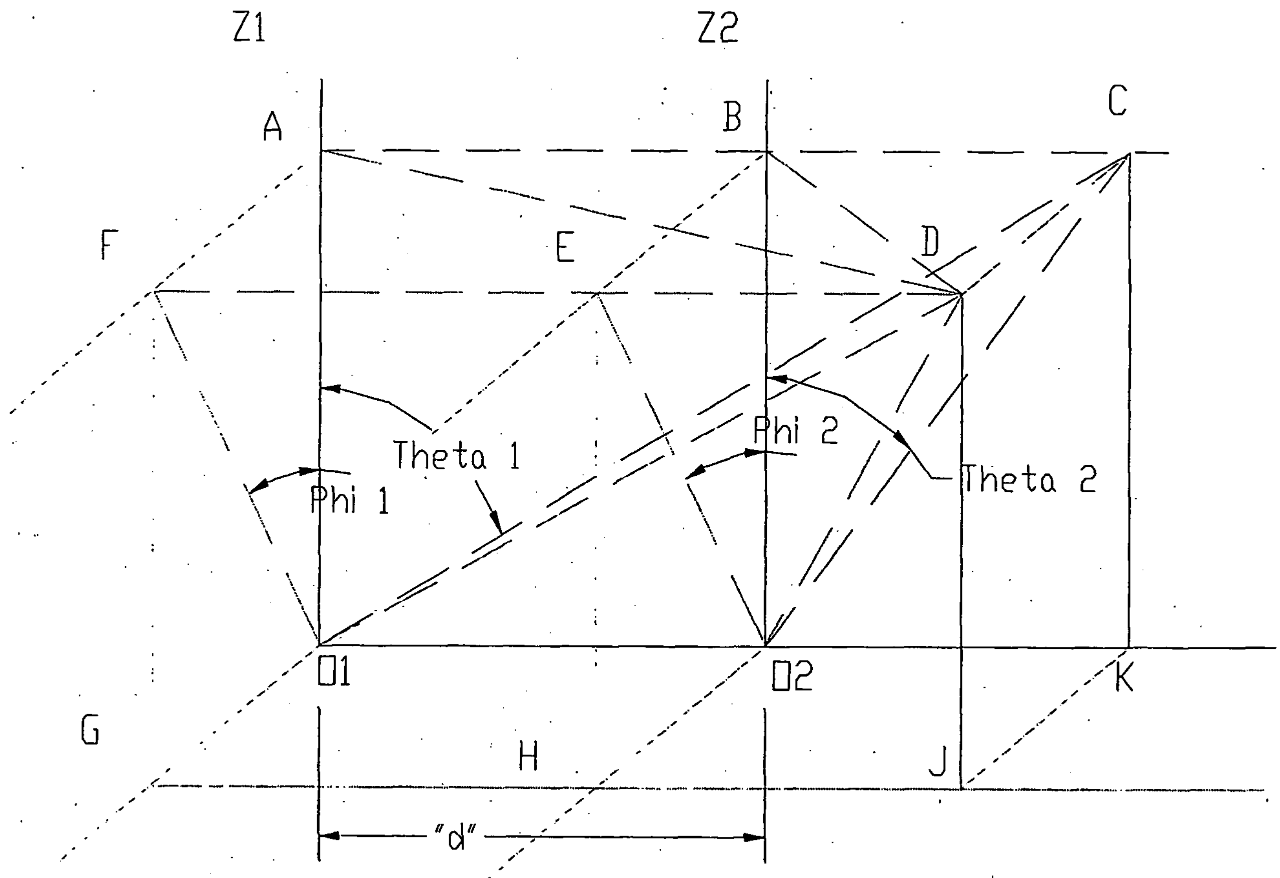

Figure 8

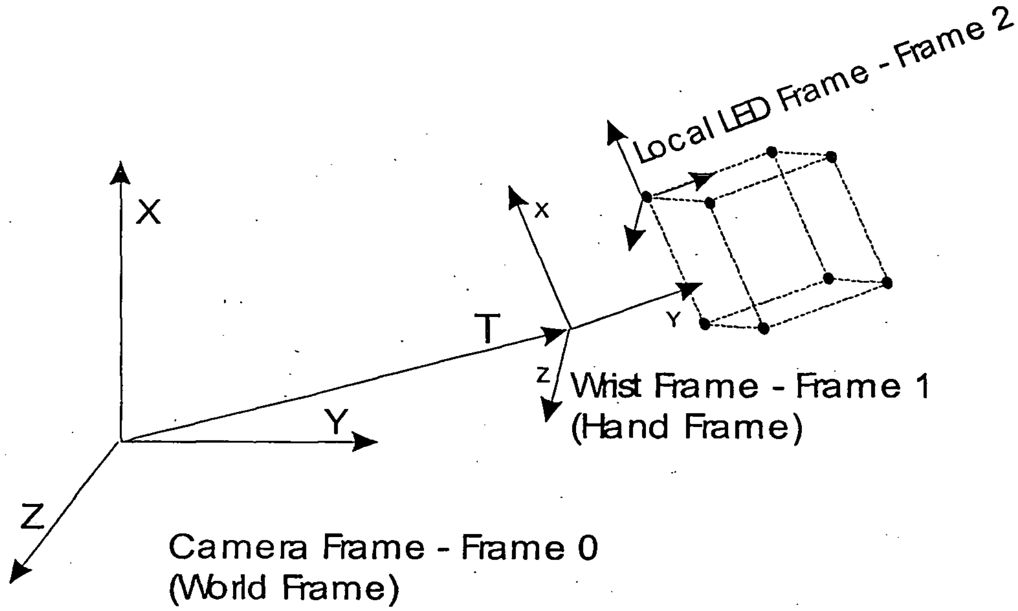
Local LED Frame - Frame 2
X
x
T
Y
z
Y
Wrist Frame - Frame 1
(Hand Frame)
Z
Camera Frame - Frame 0
(World Frame)

Figure 9

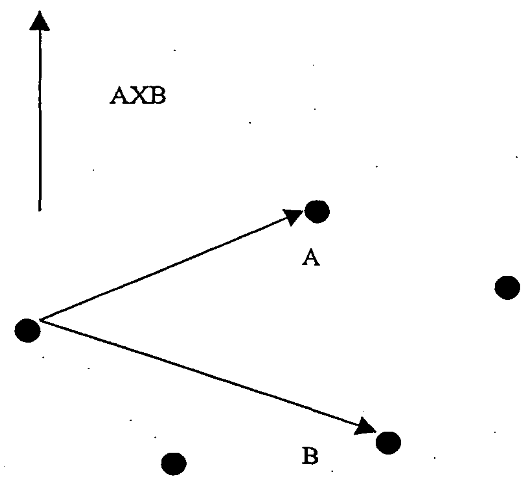

Figure 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/48224

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G09G 5/08
US CL : 345/156, 157, 158, 166, 169, 175
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/156, 157, 158, 166, 169, 175

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,988,981 A (ZIMMERMAN et al.) 29 January 1991, see the entire document.	1-27
Y,P	US 6,049,327 A (WALKER et al.) 11 April 2000, see the entire document.	1-27
Y,P	US 6,069,594 A (BARNES et al.) 30 May 2000, see the entire document.	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 MARCH 2002	08 APR 2002

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